# THE EFFECT OF AUDITORY ALERTS ON THE PERFORMANCE OF CONCURRENT TASKS

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## ABSTRACT

This paper reports results from an on-going study of the effectiveness of different kinds of aviation-based auditory alerts and the alerts' effect on the performance of other, unrelated tasks. Participants engage in tracking, gauge/light monitoring, and resource management tasks while completing a separate auditory alert identification task. Preliminary results from this multi-task approach suggest that identification responses to auditory icons are more accurate and faster than responses to tonal patterns, and secondary tasks may experience less disruption in the presence of icons than tones. In addition, the evaluation method may be used to predict the effectiveness of alerts, regardless of environment.

## 1. INTRODUCTION

A variety of auditory alert research demonstrates that auditory icons are learned and responded to more quickly than tonal patterns (e.g., [1], [2]). However, responses to alerts need to be evaluated in a more realistic environment, as alerts rarely are the only environmental stimuli that require a response. A dual task paradigm provides a cognitively demanding situation that can simulate, to a certain degree, complex real-world tasks. By incorporating alerts into a dual task, response accuracy and speed to the alerts can be measured while the participant is performing other tasks. In addition, any interference the alerts might cause with the other tasks is assessed. Alerts need to be effective in signaling an event, but they should not be disruptive to other actions that must be completed simultaneously.

Dual tasks used in the study of auditory alerts often combine the alert task with a tracking task. An early example is Wheale [3], who used either tonal alerts or speech alerts to direct attention to a Central Warning Panel which visually displayed a warning (e.g., "Engine Fire"). Participants responded to the alerts while performing a tracking task. Neither response to alerts nor tracking performance was influenced by the type of alert (tones or speech). However, tracking errors increased when alert duration increased.

Bliss and Dunn [4] required participants to respond to audio/visual alerts while engaged in the Multi-attribute Test Battery (MATB) [5]. The MATB includes tracking, resource management, and light/gauge monitoring tasks. Workload was manipulated by increasing the frequency of the auditory alerts and increasing the number of MATB tasks. Results showed that tracking performance became worse as workload increased, but alert performance did not differ under the different workload conditions. While informative, this study did not require identification of the alerts and did not report results from the other MATB tasks. Identification of alerts and a full analysis of the MATB task would provide a more detailed look at possible alert/task interactions.

Smith, Stephan, and Parker [2] used a tracking, gauge monitoring, and Air Traffic Control (ATC) task together with an alert identification task to study the effect of alerts on other tasks (auditory ATC messages are presented and subjects respond only to certain predetermined messages). Speech, tonal, and icon alerts were used, and speech and icon alerts were learned faster and retained better than the tonal alerts. For the dual task, performance with just tracking and the alert task served as a baseline, and workload was increased by adding tasks (gauge monitoring and ATC messages). Results were analyzed in terms of reaction time (RT) and accuracy to the alerts while performing the other tasks. The effect of the different types of alerts on the other tasks was not reported (e.g., tracking performance). Accuracy was very high for all of the alerts, so analysis focused on RTs. There was a main effect of alert, where speech alert RTs were faster than icons, and icons were faster than tones. RTs were not affected by the presence of the gauge task, but were slower in the presence of the ATC messages. This result makes sense, as the alert and ATC tasks are both auditory in nature.

While these representative studies explored auditory alerts beyond just learning and retention, how alerts influence other tasks is not answered fully. It is essential that potential interactions be assessed because an alert could be very effective in signaling an emergency situation, but would not be a good candidate if its presence disrupted other tasks.

The current study uses the Multi-attribute Test Battery [5] in conjunction with an alert identification task to make a more fine-grain analysis of the effectiveness of alerts as well as their effect on other tasks. All of the alerts/situations are unique to U.S. Army helicopter environments, but developing alerts for this environment is not the main goal of the study.

## 2. METHOD

### 2.1. Stimuli

A USAARL helicopter pilot identified 8 events for which an auditory alert would be useful and also provided guidance as to what kind of sounds could serve as icons. Subjects rated the different kinds of alerts for urgency and similarity, after which subjects went through a training phase and were required to identify the event that each alert signaled. Initially, three sets of alerts (8 in each set) were used; icons, which had some natural association with the situation they were alerting (e.g., helicopter rotor sound for “Low Rotor” alert), distinct/complex tonal patterns, and similar/simple tonal patterns consisting of a few sine waves (these alerts were based on parameters outlined in a military standard). The simple tonal patterns were rated the most similar to one another and were low in urgency. In addition, they were difficult to learn, with some subjects never reaching more than 70 percent correct even after multiple training/testing sessions. Thus, this alert set was removed from further evaluation. Icons frequently were learned after one repetition while the tones required more repetitions. It appears that icons required little “learning,” as the associations probably have been formed by experience in the environment/culture. If the icons are processed automatically, and do not require much attention (e.g., [6]), they probably will be effective alerts and will not interfere with other concurrent tasks. Thus, rate of learning may be a useful first step in distinguishing more effective from less effective alerts in any alert environment.

The MATB is a program that requires participants to perform a tracking task, monitor two lights and four gauges, and manage resources with “pumps” so that two “tanks” stay at approximately 2500 units. Figure 1 is a schematic of the MATB screen (from [4]). The “System Monitoring” section requires keyboard responses when lights go on or off, or when the four gauges exceed a limit. The “Resource Management” task requires that “tanks” A and B stay at approximately 2500 units. This goal is achieved by using the “pumps” (via keyboard responses) to move resources from the other “tanks.” Finally, the tracking task requires that the subject use a joystick to maintain the circle in the vicinity of the center cross area. The task somewhat simulates the cognitive demands of flying an aircraft, but is not so complex as to require a special subject population (i.e., pilots).

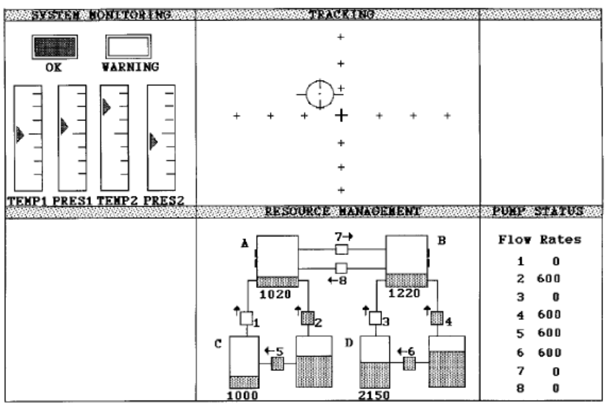


Figure 1. *The MATB screen*

### 2.2. Procedures

Five people from the USAARL community volunteered for the study. None had any aviation training, nor played video games on a consistent basis.

Using a within-subjects design, participants completed two days of testing, with a different alert set run on each day. The alert sets were very distinct from each other, and the first set of alerts did not influence learning of the second set of alerts. The order of alert sets was counterbalanced across the five subjects. The within-subjects independent variable was alert set (icons or tones) and the dependent measures were alert identification accuracy and reaction time, reaction time to the lights and gauges (monitoring task), deviation from 2500 units in the tanks (resource task), and root-mean square (RMS) deviation for the tracking task.

Participants were familiarized with the MATB program, then completed a 10-minute training session. A second, more difficult training session (more events and more difficult tracking task) was then completed. Participants then worked through an alert familiarization program where alert/associated situation pairings were learned. Finally, participants were tested on the alerts. Eight situation labels were presented visually, one auditory alert was presented, and participants clicked on the situation to which the alert referred. Each alert randomly was presented three times, resulting in 24 trials. The testing session was repeated until three or less mistakes were made. One or two sessions typically were required for the icons while up to four were required for the tones.

One more 10-minute training session was completed with the MATB and alert tasks completed simultaneously. The MATB screen, keyboard, and joystick (for the tracking task) were placed directly in front of the participant. The alert task was controlled by a separate computer, and the screen was placed at an angle to the left of the MATB screen. Participants used their left hand to click on the alert label. On the second day of testing, participants completed the alert familiarization/testing phase and one multi-task practice session. Isolated MATB training did not take place.

The multi-task testing session was 20 minutes in length. MATB monitoring and resource events occurred at least every 20 seconds, while the 8 auditory alerts (10 repetitions each) were presented at random intervals from 5 to 19 seconds. Two foils occurred for every 10 alerts, and participants were told not to respond to the foils. All tasks were treated as equally important, and participants were told to try to maximize performance on all of the tasks.

## 3. RESULTS

Results were submitted to a multivariate analysis of variance. Alert accuracy and RT, monitoring reaction time, resource tank deviation from 2500 units, and RMS tracking deviations were analyzed as a function of which auditory alert set was used (icons or tones).

Data collection is ongoing and the analysis is based on five subjects. As seen by the standard error of the mean bars in Figures 2 and 3, there was a lot of variability, especially for the tones, and no effect was statistically significant. However, there are some trends. First, as seen in Figures 2 and 3, alert identification was more accurate and faster for icons (85 percent correct, 3.47 seconds) than for tones (80 percent correct, 4.44 seconds).

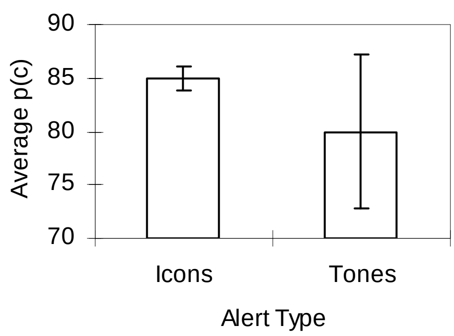


Figure 2. *Accuracy for the alert identification task.*

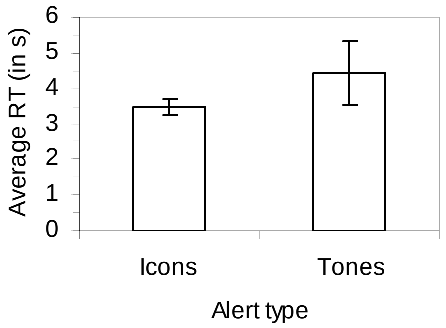


Figure 3. *Reaction time for the alert identification task.*

Response RTs for the monitoring task (lights and gauges) were about the same regardless of alert set, as were deviations in the resource monitoring task. Tracking, as measured in pixels from the tracking center target, was slightly better when icons (RMS = 28) were used than when tones (RMS = 30) were used in the alert task.

## 4. DISCUSSION

One interesting finding from this project is that variability in accuracy and RT is much less for icons than for tones. It may be that processing of the icons is more automatic and requires less processing for all listeners [6]. In contrast, the variability exhibited by the tones (with no natural associations to the events they signal) may be indicative of the learning process, and individual differences in the ability to learn the associations.

As found in other alert learning and retention studies, preliminary results from this study suggest that responses to auditory icons may be faster and more accurate compared to tonal pattern alerts, even in a more realistic, cognitively demanding environment. In terms of an aviation combat environment, the accuracy and RT differences (almost 1 second between icons and tones) could be critical. The results also suggest that auditory icons do not disrupt concurrent tasks, although more data needs to be collected to further verify this point. In a combat environment, it is essential that as much information as possible be presented in a coherent manner, and auditory alerts should not interfere with the processing of other information/performance of other tasks.

A secondary goal of the project is to develop an alert testing paradigm that will predict the effectiveness of alerts regardless of the working environment. Time required to learn the alert associations (which may reflect automaticity of the response) and performance in a cognitively demanding task may be useful predictors for assessing effectiveness in a more realistic environment.

In addition to collecting more data using the current procedures, future work will stress the listener with manipulations such as increasing the number of alerts to be remembered and adding environmental noise.

## 5. DISCLAIMER

The opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the U.S. Army or the Department of Defense.

## 6. REFERENCES

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